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GUIDELINES

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CHAPTER 4: ROADWAY DESIGN AND CONSTRUCTION

4.1 CHAPTER GOALS

This chapter will review considerations central to roadway design on BLM and FS lands including highway alignment, design criteria, earthwork and retaining walls. The goals of this chapter are as follows:

Context Sensitive Design
As discussed in Chapters 2 and Appendix G, the NEPA and Section 106 processes will provide a review of project impacts caused by the proposed highway. One goal of this chapter is to describe specific Context Sensitive Design strategies that may be used to address these impacts: planning, design and construction processes that allow for the avoidance and protection of natural and cultural resources while providing for a safe, functional and economic highway corridor.

Visual quality
Lands managed by both BLM and FS are frequently notable for their outstanding scenic qualities. Traveling for pleasure on these highways offers the primary form of recreation for many Arizonans and one that BLM and FS seek to provide. The project team should respond to this concern by creating and maintaining a highway corridor that visually blends in with the surrounding natural environment. Therefore, a second goal of this chapter is to describe the planning, design and construction of highway alignments and engineered slopes that are visually integrated with the surrounding natural landscape.

Erosion control
In order to meet the legal requirements of the Arizona/National Pollutant Discharge Elimination System, ADOT must employ erosion control techniques for all soils disturbed by construction activity (see Chapter 8). To control erosion, engineered cut and fill slopes are typically revegetated by mechanically applying seed to those slopes (see Chapter 7). Successful revegetation depends on appropriately designed slopes. A third goal of this chapter is to provide parameters for the design of these slopes.

Environmental mitigation
Finally, the NEPA document will often provide requirements for grading, slope configuration and earthwork balance. A fourth goal of this chapter is to summarize mitigation techniques that may address these NEPA requirements.

4.2 SCOPING AND NEPA PROCESSES

The success of the project team in achieving a highway corridor that is integrated into the surrounding natural landscape depends largely on the existing terrain, the proposed roadway alignment and the design criteria set forth in the project scoping document. In preparing and reviewing the project scoping document and environmental scoping document, consider the following:

Existing Topography
Roads are linear elements imposed upon nonlinear landscapes. They are typically constructed with limited grades and relatively constant widths. In contrast to highways of the past where roadways were narrow, Figure 4.1, and their profiles followed the contours of the land, contemporary highways, Figure 4.2, have wider cross sections and flatter profiles. Especially where located in hilly or

Figure 4.1 Highways of the past were narrow.

Figure 4.2 New highways have wider cross-sections and flatter profiles.

mountainous terrain, the potential for large, highly visible cut and fill slopes increases significantly using modern highway design criteria. Constructed slopes typically form the most visible elements of a highway corridor in hilly or mountainous terrain.

Alignment

During the project scoping process, several alignments may be reviewed. Impacts to existing natural and cultural resources will vary with each alignment. Alternative alignments should be carefully reviewed for possible impacts to sensitive environments, such as riparian areas, wildlife corridors, significant visual elements, scenic landforms and features, and cultural resources. When impacts to important resources are unavoidable, consider design or mitigation measures to diminish and offset these impacts such as alignment adjustments, bifurcated roadways, bridges, wildlife underpasses and improvement of degraded habitat outside the right-of-way.

Figure 4.3 Bifurcated highway.

When proposed for hilly or mountainous terrain, consider a “bifurcated” alignment, that is, a design that splits the two directions of travel so that each road can follow a relatively independent path, Figure 4.3, with smaller cut and fill slopes than might be required for a single wider roadway. During design, the project team should identify and retain important existing features and vegetation in an undisturbed median in order to reduce disturbance. Views between the two alignments should also be taken into account. Ideally, the two roadways should be treated as two independent alignments. The reader should note that while a bifurcated alignment typically results in an alignment with fewer visual impacts, it also creates a “no-man’s land” between the two alignments that is generally lost as a resource for larger wildlife species.

Design Criteria

The project scoping document will provide criteria for roadway width (including number of lanes, widths of lanes, shoulders and roadside ditches) and design speed, which, in turn, sets maximum allowable limits for roadway grades, turning radii and sight distances.

When proposed for hilly or mountainous terrain, design criteria will dramatically affect impacts to existing slopes. Even slight changes in design criteria over small distances can translate into large-scale differences for the impact that a highway corridor has on the landscape. Changes of one half percent in maximum grade, of a minimum radius of 400 feet instead of 500 feet, a total roadway width of 28 feet instead of 30 feet or a ditch width of 4 feet instead of 6 feet can result in significant changes to the sizes of associated cut and fill slopes.

Environmental Mitigation

As discussed in Chapter 2, the NEPA process may reveal the need for mitigation work both within and outside of the highway easement necessary to address impacts caused by construction of the highway to the surrounding landscape. Outside the highway easement, these mitigation requirements may include the reparation of degraded habitat, improved access to BLM/FS facilities and/or the obliteration and restoration of unneeded BLM/FS roads. Within the easement, mitigation work may include slope roughening (described later in this chapter), the laying back of slopes to open views for motorists to scenic vistas, the design of retaining walls and/or roadside barriers to avoid impacts to important resources, or other activities as described.

Geotechnical Report

Surveying necessary for the geotechnical report will typically begin during the project scoping process and the findings may impact the preferred roadway alignment. Because they involve land-disturbing activities, geotechnical investigations in the field typically require NEPA documentation prior to onset of work. The design team should be aware that completing NEPA documentation will require additional time.

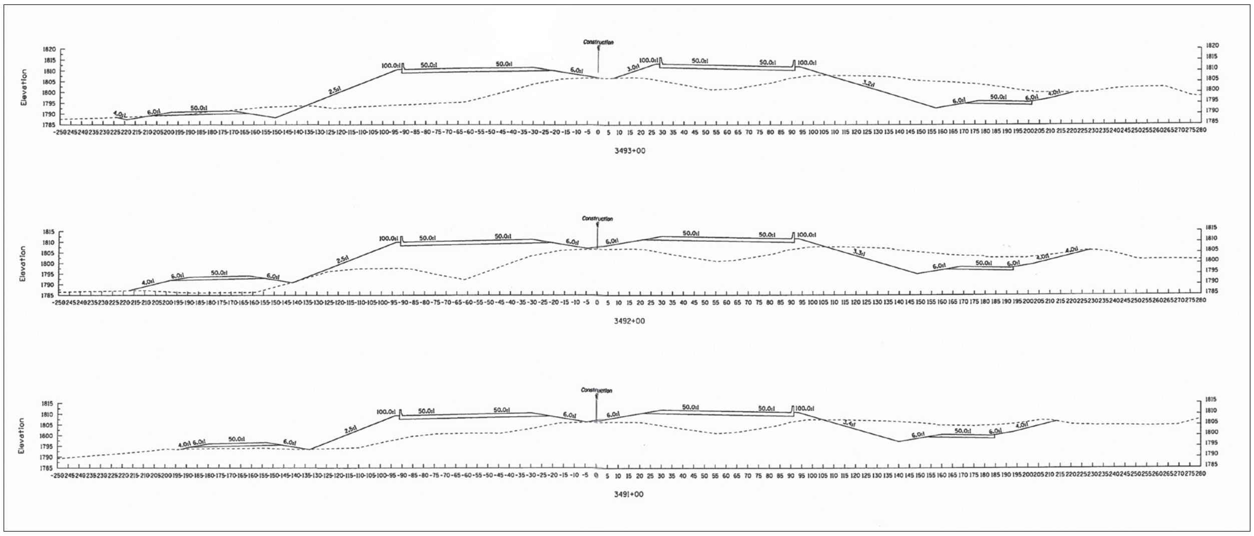

Figure 4.4 Typical cross section of a highway corridor.

4.3 DESIGN

NEPA Documents and Environmental Mitigation

During the roadway design process, the project team should regularly review NEPA documents to ensure that mitigation recommendations related to earthwork activity are met and included in the construction documents. Since they are of critical concern to BLM/FS and may be unique to the project, environmental mitigation measures require careful coordination between ADOT and BLM/FS both during design and construction. In addition, because they may be unique to the project and/or involve atypical construction practices, these measures should be "value analyzed" during design. During the construction process, these mitigation measures may **not** be "value engineered" out of the project scope.

Review Process

It is important to study the anticipated disturbances resulting from proposed earthwork. For this reason, Stage II (30%) and Stage III (60%) reviews should include visits to the project site. The centerline of the alignment should be staked for review by the design team at these stages. Staking of slope limits and limits of planned disturbance adjacent to sensitive areas should also be included at the Stage III field review.

Since the local ADOT districts will be familiar with ongoing maintenance issues and will also be responsible for maintaining completed projects, it is important that local maintenance personnel be included in the project review process.

Safety

- ***Clear Zone.*** Typical cross sections, Figure 4.4, are developed for each highway corridor. They describe the roadway, shoulder, roadside ditch and fore- and backslopes, the widths and slope ratios of which affect the clear zone.

  The clear (or recovery) zone is the total roadside border area, starting at the edge of the travelway, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope and/or a clear run-out area. The width of the clear zone varies according to the project and is to be constructed and maintained free of obstacles such as trees, boulders and manmade elements that may form barriers to errant vehicles. Slopes that are considered "recoverable" are flatter than 4:1.

  Slopes between 3:1 and 4:1 are generally considered to be "traversable," meaning that an errant vehicle cannot stop or return to the roadway but can be expected to reach the bottom of the slope. For backslopes of this nature, a clear runout area at the base of the slope that is free of obstacles is desirable.

Slopes with significant existing obstacles within the proposed clear zone may be protected by barrier (such as guardrail). Barriers should be considered where such obstacles are desirable to retain in the landscape, such as outstanding mature trees or rock features, Figure 4.5.

- ***Roadside Ditch.*** The typical roadside ditch is installed at the toe of a cut slope and its width is usually determined as a product of the drainage design. Safety concerns to consider are cut slope height, cut slope ratio, anticipated occurrence and anticipated sizes of falling rocks, undisturbed slopes above the cut, recovery area needs, sight distance requirements, blasting options and maintenance concerns such as snow storage requirements.

- ***Roadside Barriers.*** Roadside barriers function to shield the motorist from natural or built obstructions along the roadside. They are typically designed at non-traversable slopes or at fixed objects as directed by the roadway engineer.

  Barriers, Figure 4.6, may be constructed of formed concrete, masonry, galvanized steel, acid-etched steel, non-speculor steel, self-weathering steel, wood posts, steel posts, and hardware as required. Because they can be highly visible both within and outside of the right-of-way, finish materials should be carefully reviewed.
  Because they are subject to impact from motor vehicles, long-term roadside barrier maintenance is an ongoing concern. For that reason, ADOT typically prefers to minimize barrier installation. Therefore, where barrier is recommended to shield existing resources (unusual rock outcroppings, large trees, etc.), ensure that these resources are actually visible to motorists or are valuable for other reasons.

- ***Truck Escape Ramps.*** Truck escape ramps, Figure 4.7, are essential safety features in areas where there are long descending grades that may cause truck brakes to fail and result in a loss of control. Location and design guidelines for truck escape ramps are outlined in ADOT's Truck Escape Ramp Policy in the Roadway Design Guidelines.

  Because they often require extensive grading, ramps can have a significant visual impact. Therefore, when possible locate ramps in areas where they can utilize an existing grade, thereby requiring less disturbance to nearby slopes and vegetation.

Slope Stability

Slope stability refers to the resistance of a given slope to failure and includes such concerns as erosive forces, susceptibility to moisture intrusion and surface-loading conditions. Stability concerns for rock slopes include orientation and frequency of discontinuities and types of material within the discontinuities. Stability is typically directly related to soil or rock type and slope ratios. Slope stability directly affects efforts to successfully revegetate soil slopes. This issue will be discussed in greater detail later in this chapter.

Figure 4.5 Rock feature to save.

Figure 4.6 Roadside barrier of steel and wood posts.

Figure 4.7 Truck escape ramp.

Figure 4.8 Fill slope made flatter using waste material.

Earthwork

Earthwork is an important component of project design and may form the primary activity for the construction of a new highway. There are several important concerns that relate to earthwork:

- ***Earthwork Balance.*** Typically, roadway designers seek to balance cut (soil which is excavated) and fill (soil which is placed as embankment). Earthwork balance involves calculations to estimate the shrink (amount of volume reduction usually associated with soils) or swell (amount of volume expansion usually associated with rock).

  Because it is very expensive to import additional material to the project site, designers usually incorporate excess excavation into their earthwork calculations as a project-specific percentage of the overall earthwork. It will be necessary to "waste" this excess excavation if not used for construction of the roadway (waste will be described below in greater detail). For projects involving large volumes of earthwork, consider a smaller percent of that earthwork when calculating the desired waste material.

- ***Excess Excavation (Waste).*** During the design process, consider the storage and handling of any excess excavation (waste) that may be generated during construction.
  - Are there areas within the project limits in which the waste can be utilized to better integrate the highway corridor with the surrounding landscape? Both aesthetic and environmental benefits should be considered. For example, fill slope ratios may be increased (made flatter) using this waste material, Figure 4.8. This may be especially appropriate on the uphill side of an embankment where depressions will appear out of place in the landscape. Waste material may also be used to construct "false cuts" at the tops of fill slopes.
  - Is it possible to reduce the volume of waste by means of retaining walls? (Retaining walls will be discussed later in this chapter.)
  - Is it possible to reduce waste by adjusting the vertical alignment of the highway?
  - Are there areas (both within and outside the project limits) that are less visible where material can be placed?
  - Can the waste be utilized on an existing roadway that will be obliterated?
  - Are there fill slopes that can be made safer by using waste material to increase slope ratios (make flatter)?
  - Does BLM, FS or local public agencies anticipate the future construction of projects that can utilize the material such as trailhead- or overlook-parking areas?
  - If the project is one of a series within a larger corridor, consider utilizing sites to be disturbed by future phases within that corridor.
  - How will areas to receive waste be designed to be visually compatible with surrounding topography and stabilized?

- ***Cut Slope Ratios.*** In an effort to balance cut and fill, designers should generally not decrease cut slope ratios (make them steeper) in order to reduce waste material. Cut slopes are typically those slopes that are most noticed by the traveler. They are also the most difficult to revegetate because they are the most prone to erosion, Figure 4.9. In general, steeper cut slopes are more difficult to revegetate than less steeply graded slopes. Eroded cut slopes devoid of vegetation damage the environment and may be in violation of the Arizona/National Pollutant Discharge Elimination System (AZPDES/NPDES; see Chapter 8 and the ADOT Erosion and Pollution Control Manual for more information). Eroded slopes are also visually obtrusive and ongoing maintenance liabilities.

- ***Borrow.*** Borrow is additional soil or fill material transported to the project site in order to complete earthwork operations.
    - If the design process reveals a need for borrow, consider sources for that borrow. Are there areas within the project limits that can be excavated to better integrate the highway corridor with the surrounding landscape? Cut slopes may be laid back at a greater (flatter) slope ratio than typical for the project. Doing so may require additional easement.
    - Identify possible off-site borrow pits which may be excavated with fewer environmental consequences.
    - If rock is needed (typically for erosion control) and is not available from project earthwork, identify possible off-site sources that may be less expensive to access than privately-owned quarries.
    - If the project is one of a series within a larger corridor, consider utilizing sites to be disturbed by future phases within that corridor.
    - For all borrow sources, consider how those areas will be reclaimed.

- ***Geotechnical Report.*** Slope design and earthwork calculations require an accurate geotechnical analysis. The analysis should describe the nature of below-grade soils and the presence and types of rock bodies that may exist below grade. These are important considerations in the design of the roadway, slopes, and ditches in the construction sequence.

  Testing is necessary for the geotechnical report will often continue up to the Stage III (60%) documents. The project team should be prepared to revise the roadway alignment and slope configurations in response to the Final Geotechnical Report.

Appearance

Slopes may form the most visible component of a highway corridor and may dominate views both within and outside of the right-of-way. Their careful consideration is central to the design of a successful roadway. To the fullest extent practical, constructed slopes should be designed in order to blend into the surrounding landscape, Figure 4.10. Doing so will require careful attention to slope ratios, mitigation, stability and revegetation. These considerations will

Figure 4.9 Steep slopes are prone to erosion damage.

Figure 4.10 Blending slopes into the surrounding landscape.

be discussed in greater detail later in this chapter.

Easement acquisition should not be a limiting factor in the design of constructed slopes that blend harmoniously with the native landscape. Both BLM and FS will consider greater than typical right-of-way acquisition where necessary in order to design and construct a highway. Additional easement might be considered for flatter slopes or slope rounding (see below).

Revegetation
Unless constructed in rock, all slopes are to be revegetated. Concerns critical to successful revegetation are discussed in Chapter 7 and below.

Cut Slopes (Excavation)
Cut slopes, Figure 4.11, are typically the most visible slopes within a highway corridor. Final cut faces should blend with the form, grade, color and texture of the surrounding landscape.

Cut slopes are typically categorized as soil or rock cuts.

Soil Cuts

- **Slope Ratios.** In order to stabilize them, soil cuts are typically revegetated (see Chapter 7). Slopes that remain bare of vegetation following construction may not meet the requirements of the General Permit for revegetation and may be in violation of the National or Arizona Pollutant Discharge Elimination System (NPDES or AZPDES; for more information, refer to the ADOT Erosion and Pollution Control Manual). In addition, eroding slopes, Figure 4.12, stand out as visual eyesores, and therefore contradict BLM and FS goals to integrate constructed slopes into the surrounding natural environment. Finally, eroding slopes are maintenance liabilities.

  The success of the revegetation effort is largely dependent on the slope ratio. In general, flatter slopes will revegetate more successfully than steeper slopes. Slopes that are steeper than two feet horizontal for every vertical foot (2:1) are typically poor candidates for successful revegetation. Flatter slopes require a wider easement and more excavation and disturb a greater area, all of which will need to be addressed during design.

  Soil and slope conditions can change from one cut to the next. A detailed geotechnical analysis is therefore key to determining stable slope ratios.
  Grades of proposed cut slopes should be studied in relation to the existing slopes. Sliver cuts (cuts less than one foot deep) should be avoided since they often unnecessarily increase the disturbed area and provide relatively little increased stability. A short, steeper-than-average slope or a retaining wall can serve to transition between the constructed slope and the existing slope.

  Existing slope grades should also be studied for aesthetic reasons. Constructed slope ratios should be similar to those found outside the right of way in order to better integrate with the existing landforms.
- **Ripping.** Higher cut slopes and slopes steeper

Figure 4.11 Cut slopes are the most visable slopes

Figure 4.12 Eroding slopes stand out as an eyesore.

Figure 4.13 Ripping improves moisture infilteration and revegetation success.

Figure 4.14 Seed and mulch applied on steep slopes.

Figure 4.15 Mini benches increase water retention.

than 3:1 should be ripped, Figure 4.13, as they are being constructed. Soil amendments and fertilizers should be broadcast and seed and mulch applied by hydraulic equipment, Figure 4.14, in stages at appropriate intervals during the construction. Slopes flatter than 3:1 should have the fertilizer and soil amendments applied, then ripped prior to seeding. Ripping should be constructed on the contour, perpendicular to the fall line. Ripping to the specified depth improves rainfall infiltration and revegetation success.

- **Mini Benches**. For large cut slopes (more than 25 feet high), slopes that are steeper than 3:1 or slopes constructed in highly erodable soils, consider the construction of mini benches, Figure 4.15, instead of ripping. Like ripping, mini benches also increase water retention. When properly constructed, mini benches will rapidly erode, softening their appearance. Utilizing trees and larger shrubs in the revegetation effort will also help to blend slopes with surrounding vegetative cover.
- Mini benches are constructed as the slope is constructed; dimensions depend on the slope ratio. Refer to the ADOT Erosion and Pollution Control Manual for information regarding detailing and construction.
- **Track Walking**. Carefully review the need for track walking, Figure 4.16, since soil compaction typically reduces successful revegetation. Track walking should be used after, not in lieu of ripping. Track walking must be constructed so that indentations are parallel to the contour. Refer to the ADOT Erosion and Pollution Control Manual for more information.
- **Slope Mitigation**
    - **Rounding:** In order to more harmoniously blend cut slopes into the native landscape and reduce the visual impact of the highway corridor, the tops of cut slopes should be rounded, Figure 4.17. Study the existing and proposed slope ratios in order to determine appropriate rounding. The amount of rounding over should reflect the appearance of existing ridge tops adjacent to the project. In general, the higher the cut slope, the more the top of the cut should be rounded. The success of a rounded slope can be achieved by thoroughly hashing out problems during design development.

It cannot be stressed enough the importance of not skimping on rounding, and of adhering to designed plans for rounding. Rounding helps to naturalize the shape of a cut to conform to the surrounding topography. Cuts with a limited rounding call strong visual attention by contrasting to the natural landforms, and this visual impact supersedes any vegetation that may be saved. The vegetation near the edge of the cut slopes tends to die back for several years after construction due to changes in exposure and water infiltration rates and cut roots.

Vegetation and the visual impact it has on and at the edge of cuts is usually transitory, the rounding or lack of it, is what we see from now on.

Rounding may also reduce roadway maintenance. Removing additional material at the top of the cut may reduce the potential for undercutting trees or boulders from erosion.

- **Warping:** Warping is the excavation of additional material so that the cut face is not parallel to the roadway, Figure 4.18. Warping is typically performed in response to natural drainages. Where drainages intercept the top of a cut, the slope is warped back about the drainage to ensure that runoff is carried within an engineered ditch. For large and highly visible cuts, warping can also be designed to blend the slope more naturally with the native landscape.

- **Laying Back:** Where the highway corridor intercepts a major drainage and the earthwork transitions from a cut condition to a fill condition (known as a cut/fill transition), the end of the cut may be laid back: the slope ratio is progressively reduced to flatten the end of the cut. Doing so will cause the cut to appear more naturalistic and to provide a smooth transition to the adjacent earthwork. Where the highway alignment affords long views of the surrounding landscape, cut/fill transitions are typically of high visual interest to travelers.

Figure 4.16 Track Walking.

Figure 4.17 Blend cut slopes into the native landscape by rounding the tops.

Figure 4.18 Warping so that the cut face is not parallel to the roadway.

- **Through Cuts:** On projects where the earthwork may leave a small standing cut on the outside of a through cut, consideration should be given to removing the resulting berm. Advantages of leaving the berm in place include reducing earthwork, disturbance and revegetation requirements and/or possible screening of the highway corridor from adjacent viewpoints. Advantages of removing the berm may include the opening of a vista from the roadway, providing a roadside parking area, reducing shade over the pavement, improving drainage and/or eliminating an unnatural landform.

- **Crown Ditches**
  Where cut slopes intercept existing slopes, runoff from those existing slopes may erode the cut slope. Crown ditches, Figure 4.19, intercept that runoff before it crosses the face of the cut slope. When properly designed, constructed and maintained, crown ditches will not be highly visible to the traveler. Crown ditches will be described in greater detail in Chapter 6.

- **Rock Outcroppings**
  Exposed rock, where safely embedded into the subgrade, can be left in place to improve slope aesthetics, Figure 4.20. This condition should be addressed in the geotechnical analysis and report.

Figure 4.19 Crown ditch.

Rock Cuts

- **Safety**
  Of primary concern in the design of rock cuts is the stability of the finished cut. Even small rocks that become dislodged and fall onto the travelway (roadway and shoulder) can pose a serious hazard to the traveler. Therefore, it is imperative that the geotechnical analysis provides detailed, slope-specific information regarding rock types, recommended slope ratios and ditch widths and depths. Where rockfall is anticipated, the roadside ditch may be widened to contain fallen material. Widening the roadside ditch will affect the easement width and earthwork balance and should therefore be considered early in the design process.

- **Aesthetics**
  In general, rock cuts should be constructed to appear similar to rock faces found in nature in the project area. To that end and to the extent practicable, they should follow naturally occurring joints, creating irregular ledges and sheer faces, Figure 4.21. Hard competent rock will typically produce safer cuts that appear more natural than cuts constructed in softer rock. Highly fractured, unorganized cuts,

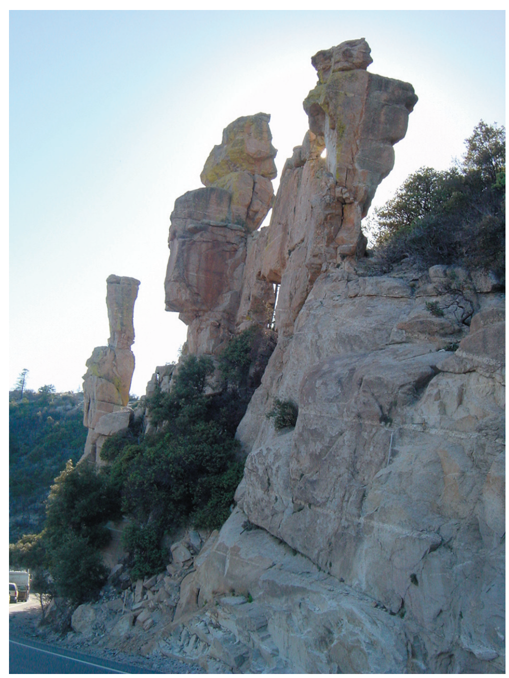

Figure 4.20 Saving rock outcroppings.

Figure 4.22, should typically be avoided as should smooth, featureless faces. On visible slopes, scars and drill-hole traces, Figure 4.23, resulting from construction equipment or blasting operations should typically be removed from finished faces.

Where the cut rock face varies significantly in color from the surrounding rock areas, a penetrating oxide stain may be applied to the rock to provide a darker, weathered rock appearance. For large rock cuts, the stain may need to be applied as the slope is constructed. Rock cuts that expose weathered rock surfaces, geologic features and colors or other natural features should not be stained.

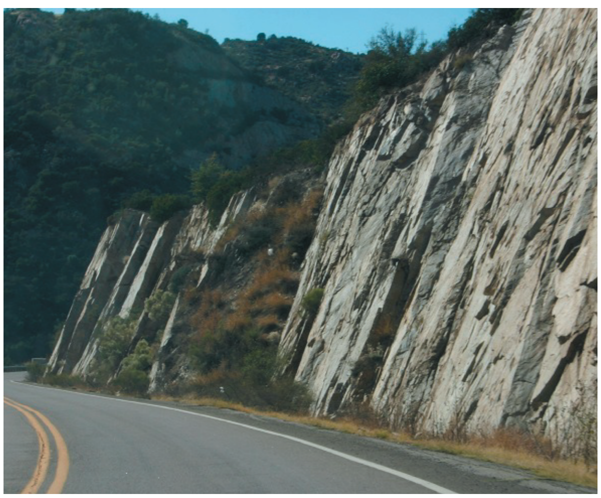

Figure 4.21 Cuts should create irregular ledges and sheer faces..

Where rock cuts are mostly invisible to motorists or from outside the right-of-way, the design team may consider excavating rock slopes that appear more artificial. Doing so may reduce construction and maintenance costs.

- **Slope Ratios**
  Rock slopes can typically be constructed at steeper slope ratios than soil or colluvial slopes. The rock type, discontinuity orientation and frequency and the height of the cut slope will determine the appropriate slope ratio. Of primary concern (as for all cut slopes) are constructability and slope stability. A slope of 0.25:1 is a general maximum slope ratio for competent rock. It may be possible to achieve

Figure 4.22 Highly fractured, unorganized cut.

  0.1:1 in extremely competent rock. However, near vertical cuts may appear to travelers to encroach into the travelway, causing drivers to shy away from the slope. For this reason, near-vertical cuts should be set back from the travel lane.

- **Mechanical Excavation**
  Since mechanical excavation is less expensive than blasting, typically a contractor will excavate rock cuts mechanically if possible. In order to achieve rock cuts that appear more natural, the contractor may be required to remove resulting scars.

- **Blasting**
  There are two general blasting techniques that are relevant to highway corridor construction: controlled blasting and production blasting.

Figure 4.23 Visable scars from drill-hole traces.

- **Controlled** blasting consists of the controlled use of explosives and blasting accessories in carefully spaced and aligned drill holes, using different explosives and delays to produce specific, free surfaces or shear planes in the rock. Controlled blasting may result in visible drill hole scars, which require scaling to remove.

- **Production** blasting consists of more widely spaced production holes drilled throughout the excavation area. Production-blasting techniques are typically employed to shatter large volumes of material for subsequent removal and processing and are not appropriate for final cut faces because of aesthetic and maintenance concerns.

  Blasting Plans: General blasting plans are required for all projects for which blasting is anticipated. ADOT will review the General Blasting Plan prior to any blasting activity. The plan typically outlines the blasting techniques proposed by the contractor and should include specific proposals for each major cut on the project.

  In addition, the contractor must submit a specific blasting plan for each major cut to include the following information: the proposed drill hole grid defining the spacing and burden; the proposed types of explosives; and the proposed timing delay. ADOT, in consultation with the contractor and the BLM/FS representative, should review the plans against the specific cuts for which they are intended for possible collateral damage to adjacent environmentally or culturally significant areas. Where rock cuts are a major component of a project, the contractor may be required to hire a blasting consultant to review all blasting plans.

  To evaluate the proposed blasting plan, **test blasts** are often required before the contractor can proceed with production or controlled blasting. Typically, the test blast will be conducted in sections up to 100 feet in length. The project engineer, the blasting consultant (if used), and the BLM/FS representative will evaluate the results of the test blast.

- **Rockfall Containment**
  Rockfall containment measures may be needed on any type of rock slope. Where such measures are considered, an analysis of potential rockfall should be performed in order to determine the potential size of dislodged material and where the rocks may come to rest. The project team should consider the visual impacts of any proposed containment systems.

  - **Rockfall ditch.** Of the containment measures described in this text, rockfall ditches are typically the least visually disruptive and often the most cost-effective containment system to both construct and maintain. Therefore, if determined by the rockfall analysis to be necessary, the project team should consider rockfall ditches first. Most ADOT projects call for the construction of a 20-foot wide roadside ditch to address drainage and safety concerns; this ditch width and the ditch depth may be increased to contain anticipated rockfall. Doing so will generate additional waste material that should be incorporated into the earthwork calculations.

  - **Rock bolting and soil nailing.** Generally used on slopes that are marginally stable, bolting and nailing consist of installing and grouting steel reinforcing bars into horizontal holes drilled into the rock face. Wire mesh can be attached to the rebar, Figure 4.24, to contain any loose rock. Rebar may also be formed into a steel framework to receive shotcrete facing. This shotcrete can be formed and painted to mimic rock outcroppings, Figure 4.25.

  - **Wire mesh.** Wire mesh or chain link may be pinned at the top of the cut and draped over slopes, Figure 4.26, as a measure to control rockfall. While it does not prevent rockfall, it prevents falling rocks from bouncing out into the travelway. Roadside ditches (or benches, where appropriate) can serve to contain the fallen rock where it may be safely removed during maintenance

Figure 4.24 Mesh attached to rebar.

Figure 4.26 Mesh draped over slopes.

operations. Because the visual impacts of this system vary widely with the mesh type and gauge, the project team should give careful consideration to the visual impact of the selected materials.

- **Fence /Barrier.** A barrier and/or fence, Figure 4.27, can be placed at the edge of the ditch area to stop rockfall from entering the travelway.

Embankments (Fill Slopes)

As discussed earlier, slope ratios are critical to the successful revegetation of disturbed slopes. Therefore, embankment (fill) slopes should be constructed at a suitable ratio for stability, thus improving rainfall infiltration for establishment and maintenance of vegetative cover. Also discussed earlier is the fact that clear zone considerations will play a key role in the design of embankment slope ratios.

In general, embankments are not as visible to the highway traveler as are cut slopes. However, they may be highly visible from areas outside the right-of-way. Similar to cut slopes, embankments should be designed to integrate with the surrounding landscape. Mitigation treatments to achieve this effect may include warping the toe of the slope and creating slopes with complex slope ratios. With respect to the latter treatment, the fill slope is graded to alternate between steeper and flatter areas. Where constructed outside of the clear zone, the flatter slopes may be appropriate areas for larger types of vegetation, such as salvaged trees. Complex slope ratios are also typically less prone to

Figure 4.25 Shotcrete facing formed and painted to mimic rock outcropping.

Figure 4.27 Fence at edge of ditch area to stop rock fall from entering roadway.

erosion from storm water runoff. The designer will need to prepare details specific to those slopes for this sort of treatment.

The toe of embankments can also be warped to avoid disturbing outstanding features such as rock outcroppings or vegetation that warrant preservation, Figure 28.

Figure 4.28 Toe of embankment warped to avoid rock outcropping.

Obliteration (Decommissioning) of Roads
Highway corridors that are no longer needed are to be physically obliterated and legally abandoned back to the appropriate federal agency. Abandoned highways will be identified during the NEPA process. During design, the project team should evaluate the need for and degree of obliteration as follows:

- Will the corridor continue to serve other uses such as for recreational off-highway vehicles, public grazing or utility access?
- To what degree should the existing cut and fill slopes be restored to their original condition?
- How visible is the abandoned corridor from outside of the right-of-way?
- To what degree should the existing drainage structures be removed and the original drainages restored?
- Should old structures and pavement be buried in place, salvaged or removed from the project area?
- Will the obliteration effort require additional material such as imported fill or rock for erosion control? The documentation of the obliteration effort may require earthwork calculations, which will require topographic survey information.
- Will contractor use areas be required to temporarily store materials such as rock or soil?
- If grades are restored to a near-original condition, how will the contractor gain access for revegetation work?

The design team should consider the contractual nature of obliteration work. Both BLM and FS consider the restoration of old highway alignments to be as important as the proper design of new roadways. Therefore, the project contract documents should clearly specify the contractor's obligations with respect to this work.

Retaining Walls
Retaining walls introduce additional environmental and aesthetic considerations into the slope design process. While the need for retaining walls is typically determined during the project scoping process, they may be considered during the early stages of the design process up to the Stage II submittal.

Wall Applications
Retaining walls may be considered for a wide variety of circumstances, a few examples of which include the following:

- Where existing slopes are steeper and longer than proposed embankment slopes.
- Where there are concerns regarding large or unsightly slopes.
- Where the proposed slope will result in a sliver cut or fill.
- Where easement width is limited.

- ○ Where existing features such as a mature forest or natural drainage may restrict limits of disturbance.
- ○ Where fill material needed for the construction of embankment slopes is limited.
- ○ Where it is desirable to minimize excavation, thereby limiting fill material.
- ○ Where protection of an embankment slope from scouring by an adjacent drainage is needed.

Wall Aesthetics
The designer should consider the constructability and aesthetics of the proposed wall: walls should typically be constructed to integrate with the surrounding landscape. Retaining walls, Figure 4.29, can be painted or stained, constructed of coarse materials (rock or exposed aggregate concrete) and/or curved to better integrate into adjoining slopes. The project team should take care to avoid wall designs that are aesthetically more appropriate for urban applications.

Wall Alternatives
Wall types and costs vary widely. Common wall types are described below:

- **Mechanically Stabilized Embankment (MSE) walls.** Created by attaching facing material to a series of metallic or fabric grids that are embedded in lifts of engineered fill, MSE walls, Figure 4.30, can be constructed with relatively little specialized equipment and quickly if the contractor is able to transport fill material directly from the point of excavation to the new wall. The facing material is typically backed by rock that can be stained to address aesthetic concerns on highly visible slopes.
- **Crib walls and Metal bin walls.** Similar to MSE walls, crib walls are gravity walls that utilize a series of open- or closed-face modules typically installed at 0.15:1 to 0.25:1 batter. The modules, Figure 4.31, are manufactured offsite and can be constructed from concrete, metal or wood that blend with the surrounding landscape. Installation is relatively easy and fast requiring little specialized equipment. To address aesthetic concerns, open-face modules offer an opportunity for seeding or installation of


Figure 4.30 Mechanically Stabilized Embankment (MSE) wall.


Figure 4.31 Crib walls can be open or closed, made of


Figure 4.29 Retaining wall integrated into surrounding landscape.

nursery-grown plant material.

- **Gabions**. Constructed of welded or twisted wire fabric cages that are filled with rock, Figure 4.32, gabions typically are stacked in terraces. The rock may be hand-placed and/or stained to create a more pleasing finish surface where the wall is highly visible. Also consider wire cage corrosion in highly visible installations.
- **Modular Block Systems.** Relatively easy and inexpensive to install, modular block (or segmental) retaining walls, Figure 4.33, employ interlocking concrete units that tie back into the associated slope. The wall may be battered depending on the manufacturer. A wide variety of colors and finishes are available to more fully integrate into the native landscape.
- **Soil nails**. Soil nails consist of installing and grouting steel reinforcing bars (rebar) into horizontal holes drilled into the face of the adjacent slope. Additional rebar is attached to these anchors to form a steel framework to receive shotcrete facing. The shotcrete can be carved and painted, Figure 4.34, to mimic natural rock outcroppings or other features.
- **Reinforced Concrete**. Typically cast-in-place using standard or custom formliners, concrete walls, Figure 4.35, allow for a wide variety of aesthetic treatments both in form and color.
- **Masonry faced**. MSE and concrete walls can be faced with masonry, or rock to blend with the surrounding terrain or other desired finish.

Construction Access

Temporary access for all aspects of slope construction should be identified early in the design process. The need for additional temporary easements should be considered in the project NEPA documentation.

The impacts of disturbance caused by anticipated temporary construction access should be studied during the design process (see Chapter 5 for information related to riparian areas impacted

Figure 4.32 Gabion wall made from wire fabric and filled with rock.

Figure 4.34 Soil nails to mimic natural rock outcroppings.

Figure 4.33 Modular Block System employing interlocking concrete units.

Figure 4.35 Reinforced concrete, typically cast-in place, and can utilize form liners.

by construction access). Where not obliterated by finished slopes, temporary access roads should typically be reclaimed to pre-construction conditions. Therefore, separate plans documenting construction access and reclamation of that access may be required in the contract documents. Restrictions on access should be specific in the construction documents: it should be made clear in the construction documents that the contractor's obligations require that work be restricted to within the right-of-way or within approved limits.

Construction Documents
Construction documents should clearly define slope treatments and rounding. The contractor's willingness to provide slope treatments will be affected by his ability to be paid for that work. On many projects, slope treatment work is incidental to other bid items (typically earthwork) and not charged as a separate bid item. Consequently, contractors are reluctant to devote significant time to that work. The following are options for incorporating slope treatments into the contract documents:

- Provide clear construction details and properly describe in the Special Provisions the contractor's responsibilities and means of payment.
- Establish separate pay items for slope treatments. Rounding, for example, can be measured by the linear foot.
- Establish Force Accounts for that work. Force Accounts typically reimburse the contractor directly for time and equipment use at an agreed-upon rate. Because it requires direct inspection of the ongoing work and can result in higher construction costs, ADOT is typically reluctant to establish Force Accounts.
- Establish clear goals and objectives during Construction Partnering, making clear to the contractor his obligations as described in the contract documents.

4.4 CONSTRUCTION

As discussed earlier in this chapter and throughout this manual, it is important to integrate resource management concerns into the process of planning, design, construction and maintenance of highways on lands managed by BLM and FS. In order to make prospective contractors aware of these resource concerns prior to the start of construction, the design team should consider including in the contract documents a requirement for a pre-bid site meeting. This meeting can serve to present and discuss special and unusual requirements such as might be included for projects constructed on BLM or FS lands.

The following items should be addressed in the contract documents as appropriate and considered for discussion both at the pre-bid and partnering meetings:

- The contractor will typically not be allowed to develop sources of water within BLM/FS boundaries that were not previously approved during the design process. As was discussed in Chapter 2, the project contract documents should clearly define approved sources of water that will be required during construction.
- Prior to any earth-disturbing activities and filing of the Notice of Intent (NOI), the contractor shall prepare and deliver to ADOT his proposed erosion control plans (SWPPP) for approval by the ADOT Engineer in consultation with BLM or FS.
- Prior to allowing earth-moving equipment to operate on BLM/FS lands, the equipment will require washing as described in the ADOT Erosion and Pollution Control Manual.
- As discussed in greater detail in Chapter 7, the salvage of topsoil and its distribution over finished slopes form an important component of successful revegetation of those slopes. Therefore, topsoil salvage should precede any earthwork activity.
- Where projects are constructed in areas with noxious and/or invasive weed species, control measures for these species may be required prior to and during construction (see Chapter 7).
- All slopes will require revegetation or other surface treatment (e.g., slope paving, gunite, rock mulch, etc.) that will resist erosion. As discussed in Chapter 7, in order to create a proper environment for successful revegetation, it is imperative that the finish soil surface remains loose and friable so that applied seed may become established and sustain vegetative cover. It is also important that the slope finish remain "rough" and uncompacted on the slope face to allow precipitation to infiltrate. Note that these slope conditions typically require close coordination between two contractors:

(1) the earthmoving contractor who performs grading and ripping and (2) the revegetation contractor who applies soil amendments, seed and mulch.

- To protect disturbed slopes from erosion, install permanent drainage control devices as soon as possible in the construction sequence (see Chapter 6).
- To protect disturbed slopes from erosion while under construction, install temporary erosion control devices as the slopes are constructed (see Chapter 8).
- Project contract documents may call for close monitoring of slope treatments early in the construction process in order to ensure desired results.

4.5 ADDITIONAL RESOURCES

ADOT Roadway Engineering Group:
http://www.azdot.gov/highways/rdwyeng/index.asp